Fermi National Accelerator Laboratory

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CDF

Measurement of the Inclusive Jet Cross Section in $p\bar{p}$ Collisions at CDF

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ABSTRACT

The status of the CDF inclusive jet cross section measurement from the 1992-93 run of the Fermilab Tevatron is described. The E_T range of the jets extends from 15 to 420 GeV. Corrections are made to the measured cross section to obtain a true transverse energy spectrum. The corrected cross section is compared with next-to-leading order (NLO) QCD calculations and to the 1989 CDF data.

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1 Introduction

Measurement of the inclusive jet cross section provides a fundamental test of QCD. At high E_T, deviation from the QCD predictions could indicate the presence of new physics processes or quark compositeness. At low E_T the measurement has some sensitivity to the parton distribution functions. Next-to-leading order calculations[1] of the transverse energy, E_T, spectrum have less overall normalization uncertainty than leading order (LO) calculations and thus provide a more precise test of QCD.

The data from the previous CDF run is in good agreement with the NLO QCD predictions[2]. We have repeated the same analysis using the much larger data set from 1992-93 run with a few improvements in the energy correction and resolution unsmearing procedure[3]. The new measurement is in agreement with the previous results.

In this paper we describe the triggers, the data set and the jet energy correction procedure. We compare the corrected cross section with the previous data and with the NLO QCD predictions. The CDF detector has been described elsewhere[4].

2 Triggers

The CDF trigger in the 1992-93 run was based on a three level trigger system. For jet studies, four triggers were used with different E_T thresholds and prescale factors to allow an acceptable trigger rate at all E_T values. The level 1 trigger was based on the energy in a single tower. At the second level (L2), events which have a cluster above a certain E_T threshold were selected. At the third level (L3), the events were reconstructed on a SGI farm and some detector noise was removed. Events which had at least one jet above an E_T threshold were selected and written to tape. The prescale factors and E_T thresholds of these triggers are given in Table 1. For the E_T range from 15 to 35 GeV we have used minimum bias data.

3 Luminosity

The luminosity calculation is based on the beam-beam counter (BBC) hit rate under the assumption that the BBC cross section is 46.8 mb. The runs where the detector was not performing properly have been removed from analysis.

The total luminosity of the 1992-93 run is $\approx 22pb^{-1}$. The fraction of the data has been used in this analysis is given in Table 2.

4 Event Selection

We select only those events in which the interaction took place within ± 60 cm of the center of the detector along the beam direction. A minimum bias data study shows that this cut is 94.11% efficient.

Background events are removed primarily by a cut on hadronic energy which is not in-time with the event. Even after this filter there are some in-time background events present in the sample. These events are removed by requiring that METSIG be less than 6.0, where METSIG is defined as the missing E_T divided by the square root of the sum of all towers with E_T above 100 MeV. Studies have shown that less than 2% real events are rejected by this cut.

To insure that the energy of the jets is well measured we restrict this analysis to the η range covered by CDF central calorimeters where the detector is very well understood. Only those jets which have absolute detector η in the range 0.1-0.7 are used.

The inclusive jet cross section is defined to be

$$\frac{1}{\Delta\eta}\int d\eta \frac{d\sigma}{dE_T d\eta} = \frac{1}{\Delta\eta}\frac{1}{\mathcal{L}}\frac{N_{jet}}{\Delta E_T} \tag{1}$$

where N_{jet} is the number of jets in the E_T range ΔE_T. $\mathcal{L}$ is the luminosity after correcting for the prescale factor and the vertex cut. $\Delta\eta$ is the η range

Table 1: Trigger threshold and prescale factors for Jet triggers

Trigger	L3 E_T Threshold	L2 E_T Threshold	PreScale
Jet 100	80	100	1
Jet 70	55	70	6
Jet 50	40	50	20
Jet 20	10	20	500

Table 2: Luminosity for various triggers used in this analysis

Trigger type	Luminosity (pb^{-1})
Jet-100	14.3
Jet-70	15.2
Jet-50	10.0
Jet-20	15.1
Min Bias	0.03

Table 3: Transverse Energy range of triggers

Trigger	E_T^{low}	E_T^{high}
Min. bias	20	35
Jet_20	35	75
Jet_50	75	95
Jet_70	95	120
Jet_100	120	420

of the data set which is 1.2 in this analysis. The E_T ranges of the various triggers in the final results are given the Table 3.

5 Unsmearing

QCD processes involve elementary partons (quarks and gluons) but the particles measured in the detector are hadrons. We have defined a jet as a cluster of particles within a cone of radius 0.7 in $\eta - \phi$ space and the energy associated with these particles as the "true" jet energy. We ignore the energy of the particles which stray out of this cone. In other words, we do not attempt to reconstruct the energy of the original parton. This definition is used in both the data analysis and in the NLO calculations. We call energy detected by the electromagnetic and hadronic calorimeter within this cone the measured jet energy. The details of the clustering algorithm are described in [5]. The measured jet energy includes the energy associated with the partons involved in the hard collision and energy which may have originated from the spectator partons (underlying event). The underlying event energy was measured from a dijet event sample by summing the energy in a cone of 0.7 at 90° to the jet direction. This energy is subtracted on average as part of unsmearing procedure described below.

Due to finite resolution of the calorimeters, jets with a certain true energy may contribute to a different measured energy bins. This will distort the spectrum as there are more jets migrating from low E_T bins to higher E_T bins because the inclusive jet Et distribution is a steeply falling spectrum. To extract the true spectrum we use an unsmearing procedure. We parameterize the true spectrum as below.

$$\frac{d\sigma(E_T^{true})}{dE_T^{true}} = Norm((E_T^{true})^{-M}(1 - x_t + Cx_T^2)^N) \tag{2}$$

$$x_T = 2E_T^{true}/1800 \tag{3}$$

Using this parameterization, we generate the smeared spectrum using the detector response functions. The response functions relate the true E_T with the measured E_T. For each E_T^{true}, the $E_T^{measured}$ is described by the four parameter distribution[3]. These response functions were generated using the CDF detector simulation and a fragmentation model which were tuned to the 1988-89 data. The generated smeared spectrum is compared with the measured one. We iterate the procedure to find the values of parameters M,N and C which give best agreement. The normalization is determined by requiring that the area under the smeared curve is same as in the data. We assume that the jets with E_T^{true} less than 5 GeV do not contribute to the our measured spectrum which starts at 15 GeV. We correct the measured data points by comparing the true and smeared spectra.

With the inclusion of the low E_T data points we have extended the cross section measurement by 3 orders of magnitude. In order to estimate the effect of extending the range of this measurement on the unsmearing procedure, we compare two true spectra, one which is derived using the full E_T range of the data, and one in which the lowest three points are excluded. We find that the shape of the unsmeared spectrum is affected when we include the low E_T points. Figure 1 shows the difference in the two physics curves. This indicates that the size of the systematic uncertainty from our current unsmearing procedure is on the order of 20%. Other systematic uncertainties are currently under study.

6 Comparison with the 1988-89 data

The corrected spectra from two runs are shown in Fig. 2. The agreement is very good over most of the E_T range. The 1992-93 data appears to be slightly lower at high E_T than the previously published result but is consistent within the systematic error on the unsmearing procedure.

7 Comparison with the QCD calculation

We have used HMRS B parton distribution functions to calculate the NLO QCD predicted rate. The corrected 1993 E_T spectrum is compared with these predictions in Fig. 3. Again the agreement is very good below 300 GeV. Above 300 GeV the data points are slightly higher than theory curve. Only statistical errors are plotted, the systematic uncertainties on this measurement are under investigation. Also superimposed is the prediction including an extra contact term in the Lagrangian[6]. The value of Λ used in the contact term is 1.4 TeV which corresponds to our previously published limit[2]. The curve is calculated using LO QCD and normalized such that it agrees with the NLO prediction at $E_T = 100$ GeV where the effects of quark compositeness are negligible.

8 Conclusion

We have extended the range of the inclusive jet cross section measurement to E_T as low as 15 GeV. With roughly $15pb^{-1}$ of data analyzed, the statistical errors in the range 35-200 are already less than 5%. The results are in good agreement with the 1988-89 data and with the NLO QCD calculation using HMRS B parton distribution functions.

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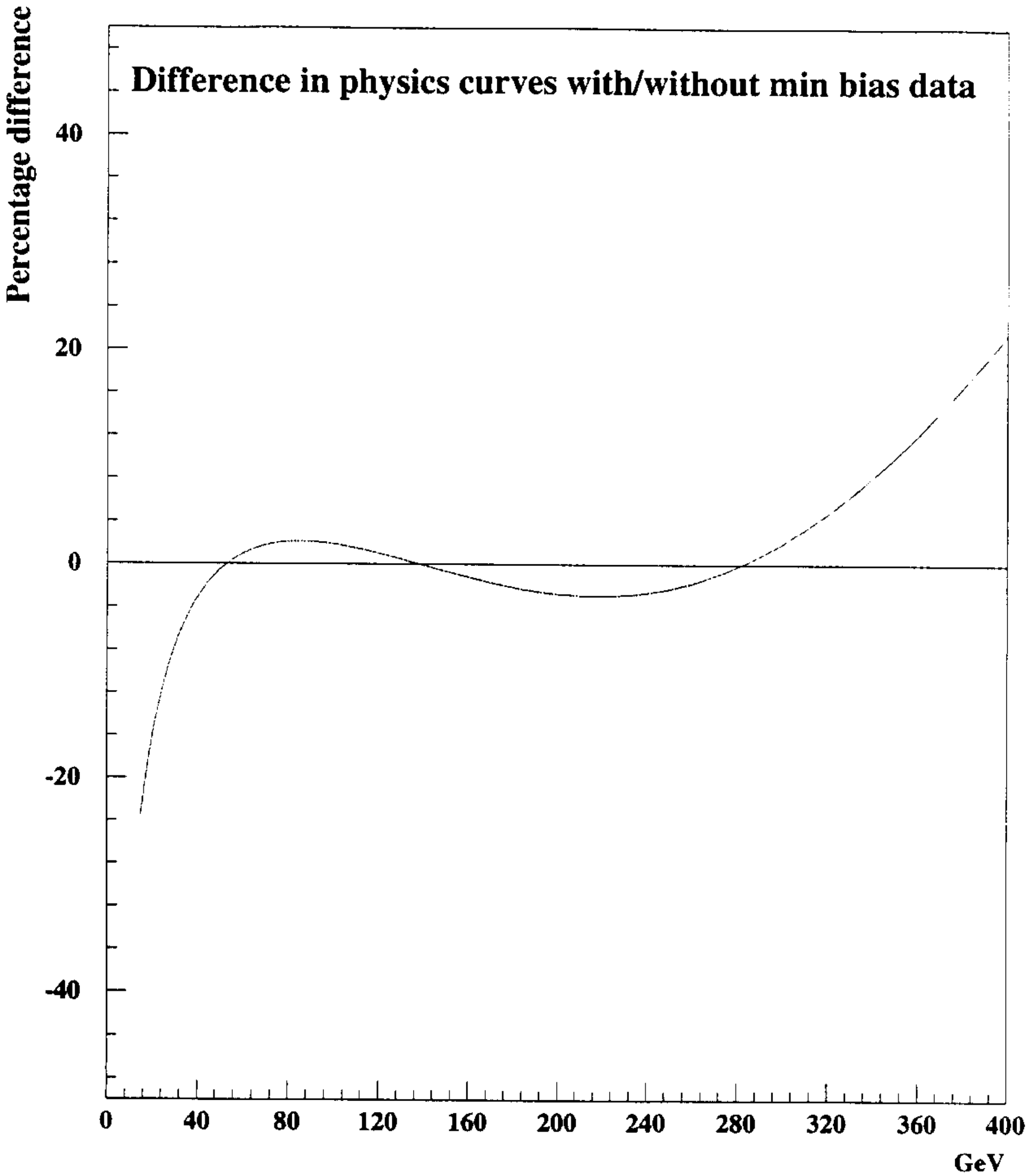

Figure 1: The difference in the two physics curves when minimum bias data is included/not included in the fit.

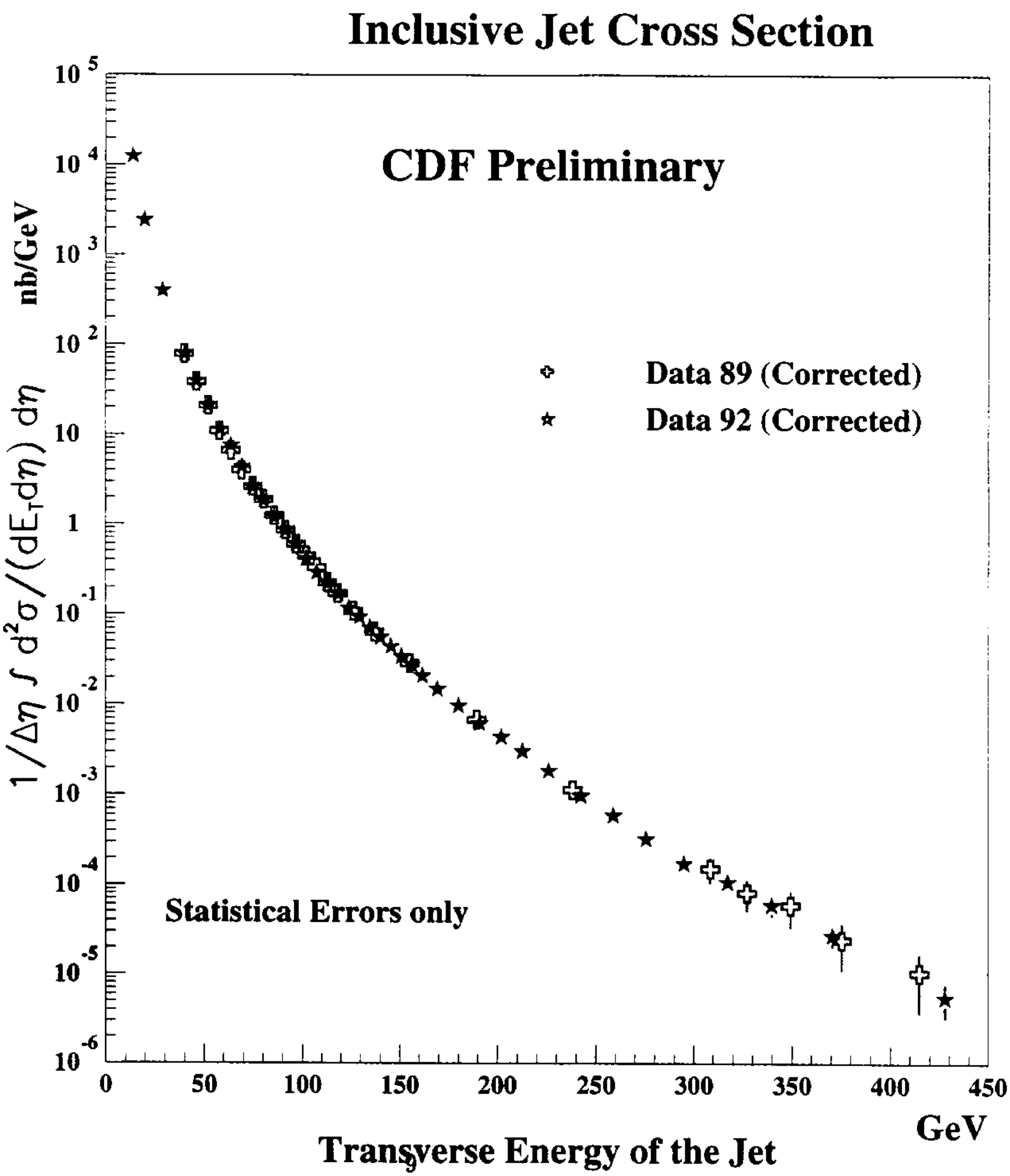

Figure 2: Comparison of the 1993 CDF Inclusive Jet Cross Section with the previous CDF result.

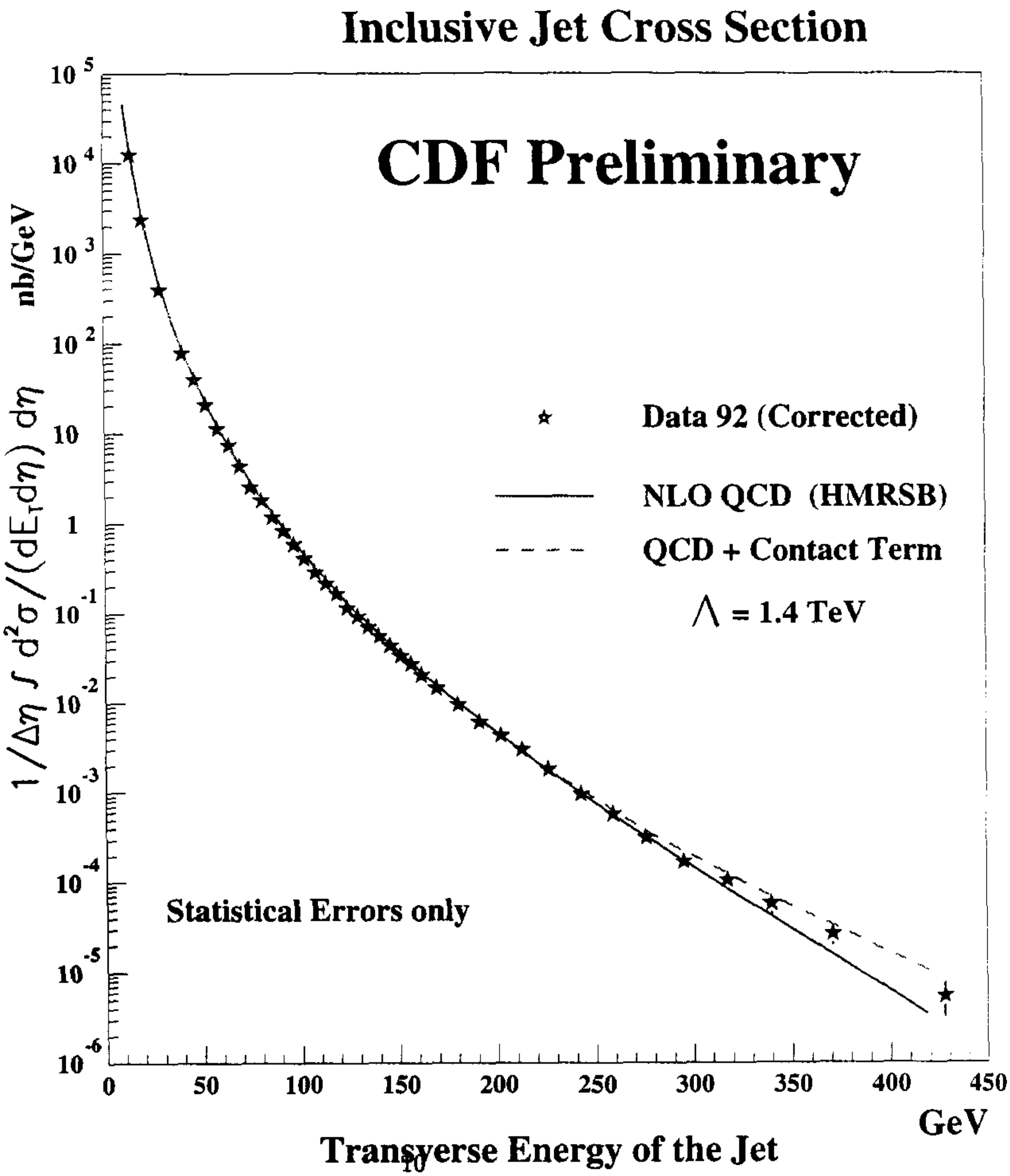

Figure 3: Comparison of Jet Cross Section with NLO QCD and with QCD+contact term predictions.